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Interannual waves in the sea surface temperatures of the Pacific Ocean

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Abstract. Various oscillatory modes of sea surface temperatures (SSTs) observed over a period of 8.8 years with the NASA Nimbus 7 Scanning Multichannel Microwave Radiometer (SMMR) and for 13 years with the NOAA Advanced Very High Resolution Radiometer (AVHRR), the latter sensing in the thermal infrared band, are described for the Pacific Ocean. The various modes are isolated by a combination of techniques designed also to accommodate non-stationary phenomena. After detrending and removing the seasonal cycle from each grid map element of the data, singular value decomposition (SVD) is used to separate the data into spatial and temporal parts to facilitate the modal analysis. Empirical Mode Decomposition is then used to separate the temporal parts of the data into approximately seven intrinsic modal functions (IMFs) for the temporal parts of the first five principal components (PCs) resulting from the SVD. A filtered time sequence of SST grids is then obtained by selecting IMFs with periods longer than 1.5 years and then reconstructing the SST grid maps from the filtered PCs. The time sequence of SMMR SSTs in the Pacific Ocean shows ENSO oscillations not only along the Equator, but also in both the North and South Pacific, with, in fact, even larger amplitudes than along the Equator. A similar analysis was applied to the SST record from the AVHRR instrument. During the period of overlap with the SMMR record, similarities occur in the equatorial region, but the records are by no means identical. The AVHRR SSTs do not show any strong oscillations in the South Pacific.

[1]

1. Introduction

Various oscillatory modes of sea surface temperatures (SSTs) observed over a period of 8.8 years with the National Aeronautics & Space Administration (NASA) Nimbus 7 Scanning Multichannel Microwave Radiometer (SMMR) and for 13 years with the National Oceanic & Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR), the latter sensing in the thermal infrared band, are described for the Pacific Ocean. The SMMR calibration and an earlier and very similar version of the technique for calculating the SSTs from SMMR radiances are described elsewhere (Gloersen 1984, Gloersen *et al.* 1992). The various modes are isolated by a combination of techniques designed also

to accommodate non-stationary phenomena (Gloersen and Huang 1999). After detrending and removing the seasonal cycle from each grid map element of the data, the time sequence of gridded SSTs is subjected to a Hilbert transform to provide complex data that preserve phase information. The spatial and temporal parts of the Complex Empirical Orthogonal Functions (CEOFs) of the gridded SSTs are then obtained by singular value decomposition (SVD). Hereafter, the CEOFs will be referred to as Complex Principal Components (CPCs). The real part of the spatial component of CPC1 is illustrated in figure 1 and its temporal part in figure 2(*b*). Ratios of the first 20 CPC eigenvalues (weights) relative to the first one are plotted in figure 2(*a*).

Contrary to popular belief, the CPCs are themselves multi-moded, as is demonstrated by Empirical Mode Decomposition (EMD) (Huang *et al*. 1998) of the first ten CPCs, containing about half of the SST signal, into approximately seven intrinsic modal functions (IMFs) for each CPC. The IMFs of the real part of the
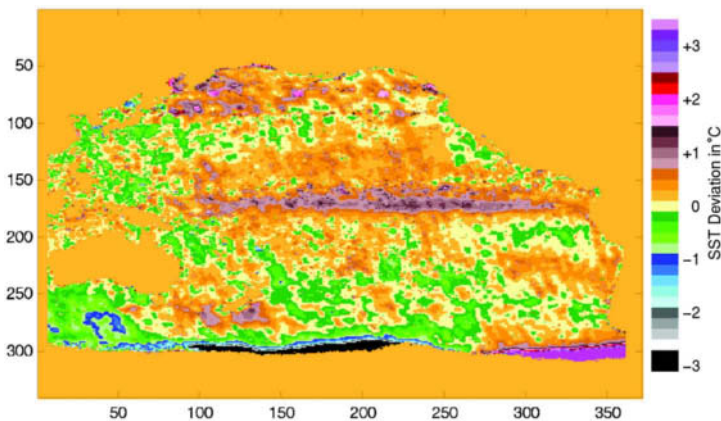

Figure 1.   Pacific Ocean. Spatial component of the real part of the first Complex Principal
       Component of the nine-year record of detrended and deseasoned sea surface
       temperatures obtained from the NASA Nimbus 7 Scanning Microwave Radiometer
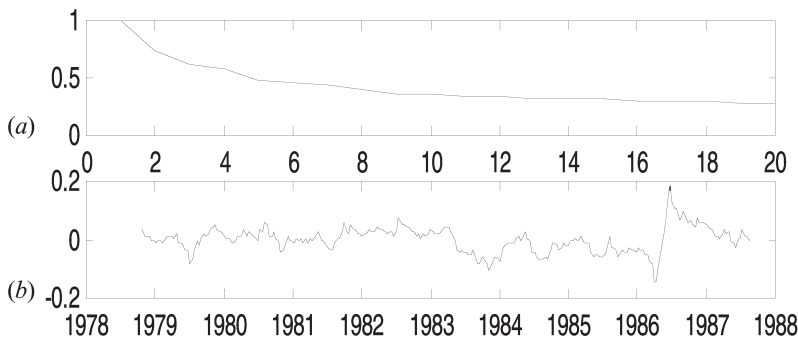   (SMMR).

Figure 2.   (*a*) Relative eigenvalues (weights) of the first 20 CPCs of the detrended,
       deseasoned Pacific SSTs of figure 1 and (*b*) temporal component of the first CPC of
       data of figure 1.